GRASSROOTS JOURNALS

**Pastures & Pastoralism**
Published by The Grassroots Institute
Website: https://grassrootsjournals.org/pp

ISSN 2817-3457 | 03(2025)

M – 00543 | Research Article | Open Access

# Determinants of Livelihood Choices in Response to Climate Variability among the Pastoral and Agro-Pastoral Communities in Northern Kenya

**Armara Macimilliam Galwab*[1], Oscar Kipchirchir Koech[2], Oliver Vivian Wasonga[3]**

[1]County Government of Marsabit, Department of Public Service and Administration, Marsabit, Kenya. Email: agalwab@gmail.com | ORCID: https://orcid.org/0000-0002-9476-7127
[2]Department of Land Resources Management and Agricultural Technology, University of Nairobi, Nairobi, Kenya. Email: oscarkip@uonbi.ac.ke
ORCID: https://orcid.org/0000-0002-8245-5185
[3]Department of Land Resources Management and Agricultural Technology, University of Nairobi, Nairobi, Kenya. Email: oliverwasonga@uonbi.ac.ke
ORCID: https://orcid.org/0000-0002-5929-6091
**Corresponding author*

**How to cite this paper:** Galwab, A. M., Koech, O. K., & Wasonga, O. V. (2025). Determinants of Livelihood Choices in Response to Climate Variability among the Pastoral and Agro-Pastoral Communities in Northern Kenya. *Pastures & Pastoralism, 03*, 21-47. Doi: https://doi.org/10.33002/pp0302

**Received**: 10 December 2024
**Reviewed**: 19 March 2025
**Revised**: 22 April 2025
**Accepted:** 25 April 2025
**Published:** 15 May 2025
Copyright © 2025 by author(s)

**Publisher's Note**: We stay neutral with regard to jurisdictional claims in published maps, permissions taken by authors and institutional affiliations.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/

Open Access

*Executive Chief Editor*
Dr. Hasrat Arjjumend
*Associate Editor*
Dr. Arushi Malhotra
Dr. Hongxi Du
*This article is edited by Dr. Hasrat Arjjumend*

## Abstract

Climate variability causes pulsed livestock and crop production, and in severe cases, production failure. It is, thus, an important predictor of household livelihood choice in pastoral and agro-pastoral communities that rely on rain-fed pastures and crops. The objective of this study was to investigate the factors that influence household livelihood choices and determine the repercussions that will help northern Kenya's pastoral and agro-pastoral production and adaptation policies. The historical self-calibrating Palmer Drought Severity Index (PDSI) was calculated every month using the 40-year monthly mean precipitation, monthly average temperature, and climatological soil available water storage capacity. The hydrological drought severity index analysis showed that Sololo and Maikona experienced the most severe floods in the years 2000, and 2020, with huge indexes of around +370, and +220, respectively. A multinomial logistic model was used to analyze primary data collected from 396 randomly selected pastoral and agro-pastoral households in four wards of Marsabit County and relate the outcome to climate variability to deduce the determinants of livelihood choices in response to climate variability among pastoral and agro-pastoral communities in Northern Kenya in a location-specific manner. Results show the likelihood of a household selecting crop farming ($p<0.05$) and other non-farming occupations ($p<0.01$), but positively associated with the likelihood of a household choosing livestock keeping. Education strongly ($p<0.05$) predicted a household's preference for paid jobs and crop farming over animal rearing. This shows that the educated household heads are more likely to prefer formal jobs and crop farming to animal rearing. Adopting alternative livelihood sources, such as raising adopted livestock species (camel, goats) and drought-tolerant crop species, is often influenced by respondents' socioeconomic characteristics. To attain a sustainable livelihood option in Marsabit County, policies that strengthen these features must be drawn and executed.

## Keywords

Multinomial logit model; Pastoralism; Livelihood; Climate variability

## 1. Introduction

Climate extremes are described as "infrequent meteorological and climatological phenomena that exceed a defined threshold". The World Meteorological Organization 2019 report and Balling et al. (2016) define extreme climate as "the occurrence of a value of a climate variable above (or below) a threshold value near the higher (or lower) ends of the assortment of observed values of the variable". Climate variability is increasingly recognized as a global phenomenon affecting various development sectors and local, national and international economies. The Intergovernmental Panel on Climate Change (IPCC) defines climate variability as a change in the state of the climate that can be identified using statistical tests and as changes in the mean and variability of climatic properties that persist for an extended time, typically decades or longer (IPCC, 2007). The consequences of climate variability are likely to be felt more acutely in developing countries, where a large proportion of the population lives in vulnerable areas, making a living primarily from natural resources, with limited institutional capacity to take proactive adaptation measures.

Pastoralism and agro-pastoralism are modes of life for people living in arid and semi-arid regions of the world. Livestock production is critical in both pastoral and agro-pastoral systems to the incomes, economies, and livelihoods of hundreds of millions of Africans and the rest of the globe (FAO, 2021). According to contemporary estimates, there are around 120 million pastoralists and agro-pastoralists worldwide, with 41.7% living solely in Sub-Saharan Africa (SSA) (Mohamed, 2019). East Africa has the highest proportion of pastoralists and agro-pastoralists, accounting to nearly half of all livestock in the SSA and providing a living for more than 30 million people in the region (FAO, 2021). The sector contributes $50-80 million in economic value to Kenya each year, 7.5% of Uganda's overall GDP, 17% of agricultural GDP, and 90% of Ethiopia's live animal export supply (CELEP, 2017).

The IPCC (2019) anticipates that climate-related threats to health, livelihoods (i.e., agriculture and livestock sectors), food security, water supply, human security, and economic growth will rise as global temperatures rise. Despite the internal and external reasons that limit the livelihoods of pastoralists and agro-pastoralists, global warming is likely to exacerbate the problem. Agriculture is the foundation of Africa's economy, accounting to the majority of livelihoods across the continent. According to the WMO (2019), the weather in Africa in 2019 was marked by sustained warming temperatures, rising sea levels, and repercussions from weather extremes and climatic events. In line with this, the Greater Horn of Africa had a significant change in climate change, from drought conditions in 2018 to floods and landslides in late 2019 (WMO, 2019). Climate extremes, such as drought and floods, are common in East Africa (Gebrechorkos et al., 2019).

Drought is a natural climatic occurrence that has far-reaching consequences for many socioeconomic sectors of any civilization, wreaking havoc on the community (Dai, 2013; Polong et al., 2019). Drought effects are expected to become more complicated, frequent, and widespread as a result of climate change and variability (Sheffield et al., 2012). For example, the drought from 2008 to 2010 affected nearly 13 million people in East Africa (Muller and Cross, 2014). The relationship between climate variability and livelihood choices is an important field of study, particularly in vulnerable areas in Northern Kenya. Climate variability influences livelihood choices, and adaptive techniques are critical for increasing resilience. These variations can include erratic rainfall, temperature changes, and extreme weather occurrences such as droughts and floods. These effects have a direct impact on natural resources, ecosystems, and human activities, especially in vulnerable locations. Livelihood choices are how pastoralists and agro-pastoralists make decisions based on their basic requirements such as food, water, shelter, and income. People choose their livelihood options based on available resources, talents, cultural norms, and environmental factors. Agriculture (crop and

livestock rearing), fishing, herding, trade, and other non-farm activities are common sources of income. Climate variability has a considerable impact on how people determine their livelihood choices. Livestock production and crop yields are affected by erratic rains and high temperatures in Marsabit County. Pastoralists and agro-pastoralists may diversify their crops and livestock species or choose drought-resistant varieties of crops and livestock. Unpredictable grazing conditions have an impact on livestock body conditions and health which may affect their productivity and marketability. Climate fluctuations may compel herders to reduce herd sizes or pursue other alternate options that are more resilient. Climate shocks may push people to relocate in quest of better chances or resources. When deciding on livelihood choices, people consider climate concerns. For instance, pastoralists and agro-pastoralists in drought-prone areas may choose drought-tolerant crops, while coastal communities may consider sea-level rise when fishing.

Climate variability has caused a drop in crop and animal production, with many households in Sub-Saharan Africa looking for alternative ways to make a living. Families engage in farm and non-farm livelihood activities such as crop production, animal rearing, and petty trading to supplement their income and cope with a harsh and challenging environment (Gebru & Beyene, 2012; Kalinda & Langyintuo, 2014; Ogundeji et al., 2022). Nkoya et al. (2004) found that the way a family makes a living is tied to their social capital, human, financial, physical, and natural assets. When adverse conditions prevail, adaptation can help reduce many of the consequences of climate impacts on livelihoods. To adapt successfully, one needs access to resources, such as money, land, knowledge, technical skills, and institutional resources (PCGCC, 2004). In addition, various social, economic, technological, and environmental trends influence farmers' ability to perceive and adapt to climate change. Knowledge of adaptation methods and factors influencing farmer decisions strengthens efforts to address climate change challenges (Temesgen et al., 2009). The pastoral system in Marsabit County, Kenya, is vulnerable to environmental degradation and ever-increasing food insecurity (Opiyo et al., 2014). Climate variability, social and economic issues such as recurring drought, a lack of basic infrastructure, and conflict are all working to limit pastoralist communities' livelihoods in the study region (Opiyo et al., 2015; Ahmad et al., 2022). Various studies have been conducted on farmers' adaptation options and their determinants in multiple countries, including Kenya, Ethiopia, and sub-Saharan Africa (Rahimi et al., 2022; Tofu et al., 2023; Temesgen, 2009). Climate variability adaptation is a critical strategy for reducing the severity and cost of climate change impacts. Adaptation measures assist farmers in mitigating losses caused by rising temperatures and decreased precipitation (IPCC, 2007; Tofu et al., 2023). While Marsabit County has previously used native ways of adaptation to disruption and damage induced by extreme climate conditions, such as drought, the recurrence of these severe climate occurrences presents additional constraints that limit adaptation options (Ericksen et al., 2013). Marsabit County, being arid and semiarid land (ASAL), is prone and vulnerable to drought. This has been exacerbated by the fact that 80% of the population relies on pastoralism for a living, which is primarily dependent on rainfall as a supply of water for pasture. However, little evidence exists on how efficient the drought early warning system is for rural residents in Kenya's ASAL regions. Few research (Silvestri et al., 2012) have focused on drought susceptibility and adaptation, with little or no emphasis on drought forecasting. A thorough drought analysis is essential for drought management and can enhance drought forecasts (Zargar et al., 2011).

The general objective of this study was to investigate the impacts of climate variability on livelihood choices among pastoral and agro-pastoral communities in Marsabit County to inform policy development and development initiatives aimed at improving pastoral livelihoods and food security. To address the general objective, the study sought to analyze the determinants of livelihood choices in response to climate variability among the pastoral and agro-pastoral communities in Northern Kenya which is the specific objective of this research paper.

## 2. Methodology

### 2.1 Study Area

Marsabit County is one of the ASALS in the Upper East that is influenced by climate variability, such as recurring drought and irregular rainfall patterns. Marsabit County has a total area of 70,961.2 square kilometers and is located in the far North of Kenya. It borders Ethiopia to the North, Turkana County to the west, Samburu County to the south, and Wajir and Isiolo counties to the east. It is located between the latitudes of 02° 45° North and 04° 27° North, and the longitudes of 37° 57° East and 39° 21° East (Figure 1). The majority of the county comprises an extensive plain that rises between 300 and 900 meters above sea level and slopes gently to the southeast. Hills and mountain ranges border the plain to the west and North, and volcanic cones and calderas punctuate it. Pastoralism and small-scale business are the main economic activities, with some small-scale crop farming such as maize, beans, wheat, pulses, fruits, khat (Catha edulis), and fishing.

The county is divided into four administrative sub-counties, which also serve as electoral constituencies: Saku, Laisamis, North Horr, and Moyale. The sub-county is divided into 20 wards, administrative locations, sub-locations, and villages. The county has tropical climatic conditions, with extreme temperatures ranging from $15^0$ Celsius to $26^0$ Celsius and an annual average temperature of $25^0$ Celsius. Rainfall ranges from 200 mm to 1,000 mm per year, with duration, amount, and reliability increasing with altitude.

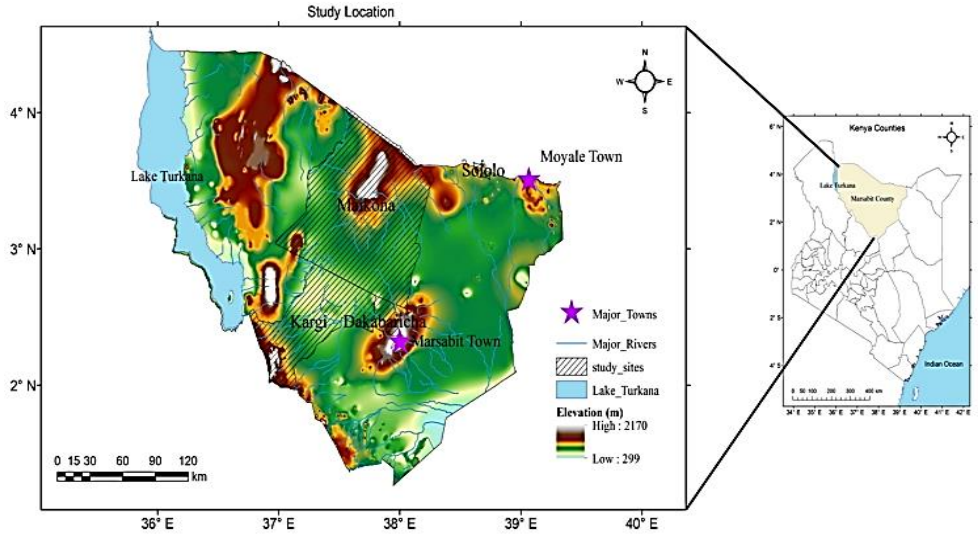



Figure 1: Map of the study area

### 2.2 Sampling Approach

A two-stage sampling procedure was employed. In the first stage, sampling was purposefully done to capture the pastoralist and agro-pastoralist locations for livelihood comparison between two areas within Marsabit County. The pastoralist areas chosen were Maikona and Kargi, while the agro-pastoralist sites were Dakabaricha and Sololo. In the second stage, villages and households within the chosen locations were randomly selected. The optimal sample size was calculated using the Fisher et al. (1991) formula for household data from the study site. Based on the equation below, a sample size of 135,694 (study population) will have a sample size of 384 households at a 95 percent confidence level.

$$Sample\ Size = \left\{ \frac{\frac{z^2 p(1-p)}{e^2}}{1+\left(\frac{z^2 p(1-p)}{e^2 N}\right)} \right\} - - - \quad \text{(Eq 1)}$$

Where:

$z$ - z-score=1.96

$p$ - Population proportion (=50%)

$e$ - Margin of error=5%

$N$ - Population Size (15,589 households at Kargi, 51,426 Households at Dakabaricha and 44,822 households in Sololo, 23,857 Households in Maikona)

$z = 1.96$, $p = 0.5$, $N = 135694$, $e = 0.05$

$$n = [1.96^2 * 0.5 * (1 - 0.5) / 0.05^2] / [1 + (1.96^2 * 0.5 * (1 - 0.5) / (0.05^2 * 135694))]$$

$n = 384.$ $(16 / 1.0028 = 383.075)$

$n \approx 384$

The number of households per village was divided by the total number of households in the study region to determine the number of households included in the survey. It was then multiplied by the sample size chosen giving the specific number of households to be included in the survey. A total of 384 households were selected for interviews using a semi-structured questionnaire.

### 2.3 Research Design

The study used quantitative research methods to identify the livelihood choices adopted by pastoralists and agro-pastoralists as a strategy for coping with the ever-changing climate in Marsabit County. Long-term precipitation and temperature datasets were used to analyze rainfall variability and temperature, key indicators of climate variability, while household surveys were conducted with household respondents using semi-structured questionnaires.

The information gathered included demographic and economic household characteristics, livestock, and crop production, climate hazard occurrence, perception level, and other relevant information. The study used different analysis technics to analyze rainfall and temperature data and household data from the field. This study used rainfall and temperature data to analyze hydrological drought severity using R programming. The positive index indicated years of flood episodes, while the negative index indicated drought. The severity of the two rainfall extremes was obtained from the drought index values. Wells et al. (2004) provide a full explanation of the modification of the original PDSI to a self-calibrating PDSI (scPDSI), which is covered in the methodological section of this paper. A multinomial logistic model was used to analyze primary data collected from 396 randomly selected pastoral and agro-pastoral households in four wards of Marsabit County and relate the outcome to climate variability to deduce the determinants of livelihood choices in response to climate variability among pastoral and agro-pastoral communities in Northern Kenya in a location-specific manner. For trend analysis, R programming was used to analyze climatic data.

### 2.4 Climate Data Source and Analysis

Meteorological data records from 1981 to 2021 were collected from the four study locations in Marsabit County. Daily rainfall data for the period 1981-2021 were obtained from CHIRPS, gridded at a resolution of 0.050 x 0.050 (approximately 5 km x 5 km over land surface), and daily temperature data were obtained from the ECMWF Re-Analysis, ERA5. The choice of Marsabit weather station was informed by the availability of reliable long-term and continuous records of rainfall data for the period under study. The rainfall datasets include 40 years of observations, enough to meet the minimum number of constant observations required for a valid climate statistical

analysis, as per WMO (2017). The data was analyzed by use of R programming software. The household data was collected using a household survey, focus group discussion, and key informant interviews by use of a questionnaire.

The Palmer Drought Severity Index (PDSI) was calculated by classifying relative soil moisture conditions into 11 categories described by Palmer (1965), ranging from -4 (very dry) to +4 (extremely wet). The index measures water supply and demand using an intricate water budget approach that considers local soil properties, precipitation records, and potential evapotranspiration (Table 1). The original PDSI does not allow for global comparisons of drought, resulting in an inadequate representation of drought in regions other than those sampled by Palmer.

Table 1: PDSI classification (Palmer WC, 1965)

| *PDSI Category* | | | *Weather* |
|---|---|---|---|
| > 4.00 | | | Extremely wet |
| 3.00 | - | 3.99 | Very wet |
| 2.00 | - | 2.99 | Moderately wet |
| 1.00 | - | 1.99 | Slightly wet |
| 0.50 | - | 0.99 | Incipient wet spell |
| 0.49 | - | - 0.49 | Near Normal |
| -0.50 | - | - 0.99 | Incipient drought |
| -1.00 | - | - 1.99 | Mild drought |
| -2.00 | - | - 2.99 | Moderate drought |
| -3.00 | - | -3.99 | Severe drought |
| < -4.00 | | | Extreme drought |

## 2.5 Computation of Self-Calibrating Palmer Drought Severity Index (sc-PDSI)

The Palmer Drought Severity Index is calculated using the principle that evapotranspiration (ET), recharge (R), runoff (RO), loss (L), potential evapotranspiration (PE), potential recharge (PR), potential runoff (PRO), and potential loss (PL) are derived from meteorological, as described in Eq.2. The PE is estimated using the Thornthwaite (1948) technique and is mostly determined by the soil's available water holding capacity (AWHC). Wells et al. (2004) served as the foundation for developing the water balance equation. This provided the foundation for calculating the moisture anomaly, which is the difference between actual and prospective precipitation. Wells et al. (2004) provide a detailed step-by-step computation of PDSI and its modification to sc-PDSI, which is given below First, the moisture departure (Eq.3) and moisture anomalies using the water balance model are calculated. The objective for the climate characteristic, K, is to alter the theoretical value of D based on climatic factors to appropriately compare PDSI values across the spatiotemporal scale.

$$K_i' = 1.5\mathrm{Log}_{10}\left[\frac{\frac{\overline{PE}_i+\overline{R}_i+\overline{RO}_i+2.8}{\overline{P}_i+\overline{L}_i}}{\overline{D}_i}\right] \quad (Eq2)$$

$$\tilde{Z} = \sum_{j=1}^{12} |\bar{d}_j| K_j' \quad (Eq3)$$

Ž represents the average yearly moisture departure, whereas Di represents the monthly moisture anomaly. The duration factors are then calculated depending on Ki. The specified PDSI value Xi is a weighted sum of the previous PDSI value Xi - 1, which represents the current climate trend, and the current moisture anomaly Zi, which indicates how wet or dry it has been over the current time. Xi was calculated using Equation 4.

$$X_i = pX_{i-1} + qZ_{i*} \quad (Eq4)$$

In real terms, the duration factors explain the sensitivity of the index to precipitation changes and the deficit thereof, p = 5 0.897 and q = 1/3. Sequentially, the 98th and 2nd percentile values of the PDSI and then SC-PDSI are computed as shown in Eq. 5.

$$X_t = \left(1 - \frac{m}{m+b}\right) X_{i-1} + \frac{CZ_t}{m+b} \quad (Eq5)$$

Thus, considering any category of drought, denoted as CZ, the computed index is calibrated as long as m and b can be calculated, where m is the line slope and b is the y-intercept.

## 2.6 Characterization of Drought Using Runs Theory

A run is a series of one or more observations of varying types preceded and followed by the same type of observation. The run approach is based on a threshold-level selection called Q (Le et al., 2019; Yevjevich, 1969). Thus, any drought event can be described by duration Du, the number of consecutive intervals of time (T) during which rainfall falls below the critical threshold, cumulative deficiency, the total number of successive deficits, and intensity I(s), the ratio of severity to duration of the drought event. It is possible to thoroughly understand this concept, as shown below:

In this study, the frequency (F) of dry episodes with a sc-PDSI ≤ -1 category was evaluated, while the risks of drought (N) were computed as the ratio of total drought length to total time. The drought frequency, F, can thus be represented as stated in Eq. 6.

$$F_j = \frac{\sum_{i=1}^{m} Du_i}{N} \times 100\% \quad (Eq6)$$

In Eq 5, N is the drought periodic time, and m is the number of drought occurrences in a certain Palmer category/class; thus, the degree of severity, S, of a drought event can be determined using Eq 7.

$$S_j = \sum_{k=1}^{D_u} scPDSI_k \,|scPDSI_k < Q_j \quad (Eq7)$$

In Eq 6 Q refers to the set drought index threshold as described earlier.

## 2.7 Data Analysis for Multinomial Logit Model

The Multinomial Logit Model (MLM) was used to predict the nominal dependent variables based on the household data collected. MLM permits the analysis of decisions across more than two categories in the dependent variable, therefore making it possible to determine the choice probabilities of different channels. The model was chosen since logistic regression is easier to implement and very efficient in training how socioeconomic and demographic status influences the likelihood of selecting a livelihood approach in response to climate variation. The multinomial logit model is the most commonly used modelling approach in decision-making processes with multiple choices. For instance, Mutura et al. (2013) used MLM to analyze the drivers of market channel choice among smallholder dairy farmers in lower central Kenya. The logit model considers three or more alternative responses and enables decision analysis and preference of possible outcomes for various alternative options (Nkamleu and Kielland, 2006). The Multinomial logit model can be expressed as follows:

$$\Pr(Y_i = 1) = \frac{e^{\beta' \; i' \; * X_i}}{1 + \sum_{K=1}^{K-1} e^{\beta' \; k' \; * X_i}}$$

$$\Pr(Y_i = K - 1) = \frac{e^{\beta_{k'} \; -i * X_i}}{1 + \sum_{K=1}^{K-1} e^{\beta' \; k' \; * X_i}}$$

$$\Pr(Y_i = K) = \frac{1}{1 + \sum_{K=1}^{K-1} e^{\beta' \; k' \; * X_i}}$$

Where Y represents households 1, 2, 3, 4..... N, each with a set of sustainable strategies (j = 0, 1, 2, 3, 4.....1, 2, 3, 4.....J) with different livelihood approaches. The vector Xi has the type K x I and represents the socioeconomic status of every household under

ideal conditions. However, xi influences the possible feedback outcome (Prob. (Y = j| Xi); j = 0, 1, 2, 3..... J. Therefore, potential multicollinearity among explanatory variables was also tested in a preliminary analysis, where it was found not to have any potential influence on estimates from the model. Multinomial logic is defined as a relationship between the likelihood of selecting alternative j and a set of independent factors Xi (Green, 2003).

The household strategies were categorized into five groups: category 1 (crop production), category 2 (forestry activities), category 3 (livestock production), category 4 (fishing), and category 5 (any other non-farming activities). The estimated coefficients were compared to the base category (crop production as a livelihood strategy). The above five explanatory variables for the multinomial logit model are the factors influencing the choice of livelihood. They are a function of some climatic factors and the socioeconomic characteristics of farm households. These variables were hypothesized as Sex of the household head (if male, 1; if female, 0), age of the household head (in years), marital status (couple 1, unmarried 0), household size (0 = below, 1 = 4 and above), education of the household head (0 = uneducated, 1 = educated), precipitation (annual mean rainfall level in mm), and temperature (average of the area in degrees Celsius). The climatic factors (rainfall and temperatures) may vary depending on the location (Table 1).

Table 2: Explanatory variables used in the Multinomial Logit Model

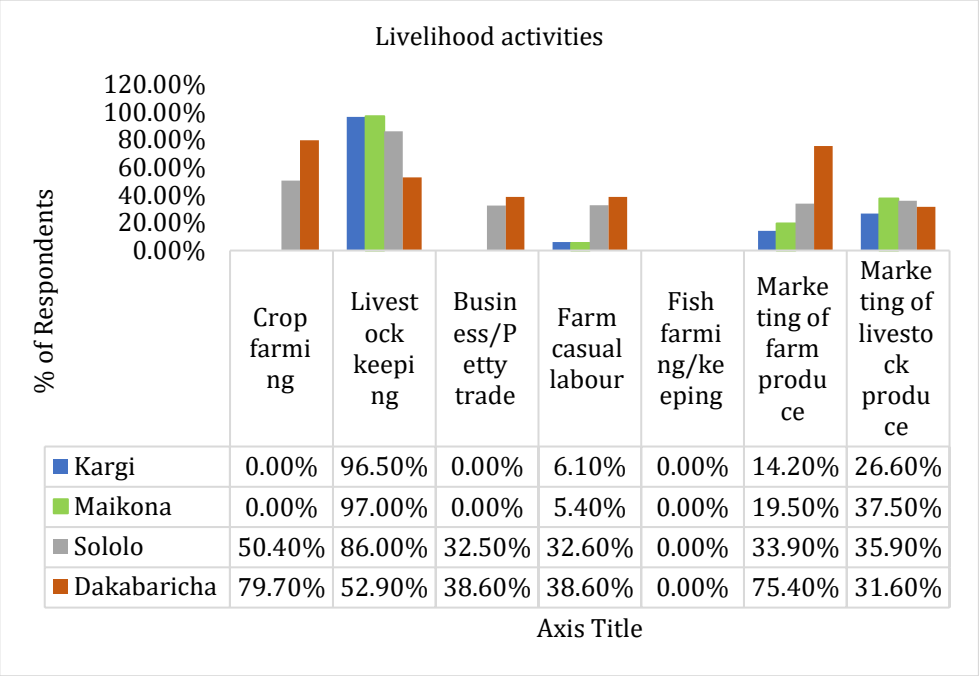
| *Variable* | *Codes* | *Description* |
|---|---|---|
| Sex | 0=Female, 1=Male | Categorical |
| Age of household head | years | Continuous |
| Marital status | 0=Unmarried, 1=Married | Categorical |
| Household size | 0=Below 4, 1=4 and above | Categorical |
| Education | 0=Uneducated, 1=Educated | Categorical |
| Change crop | 0=No, 1=Yes | Categorical |
| Intervention made | 0=No, 1=Yes | Categorical |
| Temperature | - | Continuous |
| Rainfall | - | Continuous |

## 3. Results

### 3.1 Livelihood Profile of the Respondents

Figure 2 shows the proportional distribution of respondents in the study region based on their livelihood profile. The study was undertaken in four wards in Marsabit County. Kargi and Maikona wards are pure pastoral areas. The communities residing in these regions keep different species of livestock. The Dakabaricha and Sololo regions are agro-pastoral areas where the local community practices small-scale crop farming and at the same time keeps livestock. The majority of respondents (96.50% in Kargi and 97% in Maikona) reported livestock keeping as their primary source of livelihood, while a significant proportion of respondents in the agro-pastoral region (Dakabaricha 79.7%, Sololo 50.4%) indicated crop farming as their primary source of income. Furthermore, most respondents in the agro-pastoral regions of Dakabaricha (38.6%) and Sololo (32.5%) practiced business. In contrast, marketing of livestock products (milk and meat) was reported by a small proportion of 26.6%, 37.5%, 35.9%, and 31.6% in Kargi, Maikona, Sololo, and Dakabaricha, respectively. Other livelihood options practiced by respondents included the marketing of farm produce by 14.2% of households in Kargi, 19.5% of households in Maikona, 33.9% of households in Sololo, and 75.4% of households in Dakabaricha, and mixed farming by 14.2%, 19.5%, 33.9%, and 75.4% in Kargi, Maikona, Sololo, and Dakabaricha, respectively. Most of the

sampled communities reported having little or no significant secondary livelihood sources. As a result of the lack of a diverse range of livelihood choices, communities will be less resilient to the effects of climate variability.




| | Crop farming | Livestock keeping | Business/Petty trade | Farm casual labour | Fish farming/keeping | Marketing of farm produce | Marketing of livestock produce |
|---|---|---|---|---|---|---|---|
| Kargi | 0.00% | 96.50% | 0.00% | 6.10% | 0.00% | 14.20% | 26.60% |
| Maikona | 0.00% | 97.00% | 0.00% | 5.40% | 0.00% | 19.50% | 37.50% |
| Sololo | 50.40% | 86.00% | 32.50% | 32.60% | 0.00% | 33.90% | 35.90% |
| Dakabaricha | 79.70% | 52.90% | 38.60% | 38.60% | 0.00% | 75.40% | 31.60% |

Figure 2: Major livelihood activities practiced by respondents in Marsabit County

### 3.2 Temporal Characteristics of Dry Events in the Pastoral Region of Kargi

Table 3 presents the temporal distribution of years of droughts and flood episodes in Kargi. The temporal series of self-calibrating Palmer Drought Severity Index (scPDSI) calculated over 40 years, from 1981 to 2021, were investigated for spatial signals to identify the geographical range of mild-severe drought occurrences over Marsabit using simple covariance matrix analysis. The runs were designed to capture moderate, severe, and extremely severe dry occurrences. Analysis of hydrological drought severity showed that pastoral regions have been experiencing both drought and flood episodes over the last four decades. Kargi had the most severe flood episodes of +200 in the year 2000, 2017, and 2020, respectively (Table 5). While the year 2005 had the most severe drought, denoted by a large negative index of around -120. The drought episodes were more intense as compared to floods and had almost similar magnitudes in the pastoral region as depicted by the results in table 5. However, the drought was prolonged for as long as 6 years, especially from 1991 to 1996. These Prolonged droughts can cause poor pastures and fodder, resource-based conflict, crop failure, food insecurity, water shortages, and loss of livelihoods, while the flood episodes can sweep away farms and animals and at times lead to outbreaks of human and livestock diseases making the community more vulnerable to the impact of climate variability. The findings of this study have important significance for understanding drought patterns and informing climate resilience measures in Marsabit County and elsewhere. The temporal distribution and severity of droughts over four decades in the study region provide policymakers and stakeholders with historical data to better allocate resources to the most affected regions and communities, prioritize drought-prone areas, and anticipate and prepare for future drought events. The research distinguishes drought occurrences in Kargi from other agro-pastoral regions such as Dakabaricha and Sololo. These regional disparities highlight the importance of targeted solutions that address the specific peculiarities of each area.

The severity of drought occurrences is determined by their duration, or the amount of time Marsabit County is without precipitation. Extreme droughts can have a catastrophic effect on the region's fragile ecosystems, triggering biodiversity loss and diminishing natural systems' ability to offer essential functions such as water filtration, flood control, and carbon sequestration. Pastoral communities in Kenya's drylands, particularly residents of Kargi ward in Marsabit county, which are dependent on rainfed agriculture, are especially exposed to the effects of drought and other climate variability. Efforts to help these pastoralists adapt to changing conditions and diversify their livelihoods, such as the introduction of drought-resistant livestock species, apiculture, and initiation of other income-generating activities are critical to ensuring food security and long-term livelihoods in the future. These findings are consistent with those of Mwangi et al. (2014), who identified drought years 1983-1984, 1992-1993, 1999-2000, and 2009-2011 utilizing various techniques for drought research. Prolonged droughts can have an extensive impact on livelihoods, affecting many elements of human well-being. Droughts drastically deplete soil moisture, limiting agricultural development and pasture establishment in an area leading to lower yields or complete crop and pasture loss. This has a direct influence on the income of the pastoral community and food security in the impacted region. These heightened droughts can lead to lack of water for the animals and poor pasture regrowth in the study region thereby affecting the livestock body condition. Malnutrition, poor milk output, and even death are all common problems for livestock. The local pastoral economy suffers when agricultural output declines and land prices may fall, while unemployment may grow as a result of reduced output. Further, rising temperatures due to climate change affect evapotranspiration which has an impact on both agricultural water availability and ecological health. The larger magnitude of floods may be of great advantage if rainwater harvesting is taken into consideration by the local community and the development agencies.

Table 3: Drought severity index for Kargi 1981 – 2021

| *Period of occurrence* | *Peak* | *Duration* | *Severity* | *Intensity* | *Interarrival* |
|---|---|---|---|---|---|
| Jan 1980 to Feb 1981 | Feb 1981 | 12 | 34.37 | 2.864167 | 21 |
| Dec 1981 to Mar 1982 | Mar 1982 | 4 | 6.93 | 1.732500 | 15 |
| Mar 1983 to Apr 1983 | Mar 1983 | 2 | 2.17 | 1.085000 | 3 |
| Jun 1983 to May 1985 | Jun 1984 | 24 | 62.69 | 2.612083 | 30 |
| Dec 1985 to Mar 1988 | Mar 1988 | 28 | 54.84 | 1.958571 | 59 |
| Nov 1990 | Nov 1990 | 1 | 1.20 | 1.200000 | 5 |
| Apr 1991 to Mar 1997 | Jun 1992, May 1994, Mar 1997 | 72 | 198.20 | 2.752778 | 90 |
| Oct 1998 to Mar 2012 | Jun 2000, Jun 2006 | 162 | 362.05 | 2.234877 | 186 |
| Apr 2014 to Nov 2015 | Jun 2014 | 20 | 28.88 | 1.444000 | 21 |
| Jan 2016 to Oct 2016 | Mar 2016 | 10 | 14.51 | 1.451000 | 60 |
| Jan 2021 to Nov 2021 | Nov 2021 | 11 | 16.16 | 1.469091 | 12 |

### 3.3 Drought Severity for the Maikona Region

Table 4 illustrates the analysis of the drought severity index for the Maikona region of the study. A total of nine (9) mild drought, six (6) moderate drought, and one (1)

severe drought were observed respectively with the most intense drought being observed in the year 1984 (Table 4). The years that Maikona experienced mild droughts were 1983, 1988, 1990, 1998, 2009, 2013, 2014, and 2018; moderate droughts were experienced in the years 1981, 1997, 2000, 2001, 2006, and 2021 while severe drought was experienced in the year 1984.

Table 4: Drought severity index for Maikona 1981 – 2021

| *Period of occurrence* | *Peak* | *Duration* | *Severity* | *Intensity* | *Interarrival* |
|---|---|---|---|---|---|
| Jan 1980 to Mar 1982 | Feb 1981, Mar 1982 | 25 | 60.52 | 2.420800 | 36 |
| Ma 1983 to Jun 1983 | Mar 1983 | 4 | 4.48 | 1.120000 | 7 |
| Oct 1983 to Dec 1984 | Jun 1984 | 15 | 45.63 | 3.042000 | 25 |
| Nov 1985 to Mar 1988 | Mar 1988 | 29 | 55.66 | 1.919310 | 58 |
| Sep 1990 to Jan 1991 | Dec 1990 | 5 | 6.62 | 1.324000 | 7 |
| Apr 1991 to Jul 1997 | Mar 1997 | 76 | 178.51 | 2.348816 | 84 |
| Apr 1998 | Apr 1998 | 1 | 1.03 | 1.030000 | 6 |
| Oct 1998 to Dec 2007 | May 2000, Oct 2001, Jun 2006 | 111 | 288.71 | 2.600991 | 126 |
| Apr 2009 to Jun 2010 | Apr 2009 | 15 | 20.23 | 1.348667 | 25 |
| May 2011 to Mar 2012 | Jun 2011 | 11 | 15.25 | 1.386364 | 31 |
| Dec 2013 | Dec 2013 | 1 | 1.01 | 1.010000 | 3 |
| Mar 2014 to Oct 2015 | Jun 2014 | 20 | 30.12 | 1.506000 | 22 |
| Jan 2016 to Oct 2016 | Oct 2016 | 10 | 16.52 | 1.652000 | 24 |
| Jan 2018 | Jan 2018 | 1 | 1.59 | 1.590000 | 9 |
| Oct 2018 to Nov 2018 | Nov 2018 | 2 | 3.08 | 1.540000 | 27 |
| Mar 2021 to Dec 2021 | Nov 2021 | 8 | 8.51 | 2.836667 | 36 |

Analysis of hydrological drought severity showed that Maikona has been experiencing both drought and flood episodes and the year 2020 had the most severe flood episode denoted by a large positive index of around +220 while the year 2000 had the most severe drought denoted by a large negative index of around -190 (Table 5). The drought episodes were more intense as compared to floods and had almost similar magnitudes in the pastoral region as depicted by the results in table 5. This is an indication of climate variability and change in the study area. Both droughts and floods have great implications for the livelihoods of these pastoralists. Prolonged droughts in the region can have a devastating impact on the livelihoods of pastoral communities in Kenya, leading to drying of groundwater sources, poor pasture, food and water shortages, and loss of animals while the flood episodes can sweep away farms and animals. In conclusion, the region has been exposed to both frequent drought and floods and with prolonged drought, which may adversely affect its livelihoods that are dependent on rains. Over the previous decade, the intensity of drought in Marsabit County has decreased significantly. However, it is unclear what is leading to this shift in events, given that recent research (Dai, 2013; Ongoma et al., 2018) has reported an increase in the frequency and severity of drought events over the greater East African region. Drought is a climatic and meteorological event caused mostly by fluctuations in

hydrometeorological variables such as precipitation, temperature, and soil moisture (Ayugi et al., 2020). The intensity of a drought episode is determined by precipitation anomalies, with persistent deficits resulting in worsened scenarios (Ayugi et al., 2020; Spinoni et al., 2020). As a result, it is necessary to investigate changes in these hydrometeorological causes of drought to adequately prepare for proactive contingency measures aimed at drought mitigation and long-term resilience.

Zhao and Dai (2017) attributed the wetness pattern over East Africa to significant ITCZ feedback from the Indian Ocean. Despite projected future warming, the strong shift indicating an increase in rainfall events is consistent with research by Kent et al. (2015), which found no causal relationship between global average temperature unpredictability and projected shift in precipitation at the end of the twenty-first century. The study, on the other hand, noted that local precipitation variability across the study region is mostly due to convection and convergence spatial changes, which are linked to systems such as trends in sea surface temperature (SST) and changes in land-sea thermal interaction. The inference of several research to clarify the changes in rainfall projections demonstrates the complexity of regional rainfall variations, which leads to significant uncertainty regarding the impact.

Table 5: Drought severity index for the agro-pastoral region of Kargi and Maikona

| *Wards* | *Years of drought episodes* | *Magnitude* | *Years of flood episodes* | *Magnitude* |
|---|---|---|---|---|
| Kargi | 1983 | -70 | 1981 | +80 |
| | 1984 | -60 | 1982 | +100 |
| | 1986 | -40 | 1985 | +30 |
| | 1987 | -60 | 1988 | +60 |
| | 1991 | -80 | 1990 | +100 |
| | 1992 | -30 | 1997 | +200 |
| | 1993 | -70 | 1998 | +60 |
| | 1994 | -60 | 2000 | +200 |
| | 1995 | -40 | 2002 | +70 |
| | 1996 | -40 | 2003 | +20 |
| | 1998 | -30 | 2004 | +40 |
| | 1999 | -80 | 2006 | +50 |
| | 2003 | -20 | 2011 | +60 |
| | 2005 | -120 | 2012 | +60 |
| | 2007 | -70 | 2013 | +70 |
| | 2008 | -50 | 2014 | +70 |
| | 2009 | -110 | 2015 | +40 |
| | 2010 | -50 | 2018 | +140 |
| | 2016 | -70 | 2019 | +30 |
| | 2017 | -60 | 2020 | +200 |
| Maikona | 1981 | -50 | 1982 | +90 |
| | 1983 | -50 | 1985 | +60 |
| | 1984 | -60 | 1988 | +40 |
| | 1986 | -40 | 1989 | +10 |
| | 1987 | -30 | 1990 | +70 |
| | 1991 | -70 | 1997 | +190 |
| | 1992 | -30 | 2002 | +80 |
| | 1993 | -50 | 2003 | +20 |
| | 1994 | -30 | 2004 | +30 |
| | 1995 | -10 | 2006 | +70 |
| | 1996 | -110 | 2011 | +80 |
| | 1998 | -40 | 2012 | +40 |
| | 1999 | -70 | 2013 | +100 |
| | 2005 | -30 | 2015 | +50 |
| | 2007 | -50 | 2018 | +120 |

| *Wards* | *Years of drought episodes* | *Magnitude* | *Years of flood episodes* | *Magnitude* |
|---|---|---|---|---|
| | 2008<br>2009<br>2010<br>2014<br>2016<br>2017<br>2021 | -60<br>-100<br>-40<br>-70<br>-20<br>-30<br>-50 | 2019<br>2020 | +60<br>+220 |

### 3.4 Drought Severity for the Dakabaricha Region

Table 6 presents the temporal distribution of the droughts in Dakabaricha over the last four decades. The most severe dry season in Dakabaricha occurred between October 1998 and October 2004, lasting 73 months, followed by the May 1991 to September 1995 dry spell, which lasted 53 months (Table 6). However, it is unclear what is leading to this shift in events, given that recent research (Ongoma et al., 2018) has reported an increase in the frequency and severity of drought events over the greater East African region. From the analysis, it is observed that eleven (11) mild and six (6) moderate drought years were observed, with the most intense observed in 1981 and 2000, respectively. Dakabaricha experienced mild droughts in 1982, 1986, 1988, 1990, 2005, 2006, 2007, 2011, 2014, 2016, and 2021, whereas moderate droughts were experienced in 1981, 1984, 1992,1994, 1997, and 2000 (Table 6). Over the previous decade, the intensity of drought in Marsabit County has decreased. However, it is unclear what is leading to this shift in events, given that recent research (Dai, 2013; Ongoma et al., 2018) has reported an increase in the frequency and severity of drought events over the greater East African region. Because of its geographical proximity to Marsabit Mountain, the Dakabaricha region is less affected by drought due to high annual rainfall amounts and low temperatures than the pastoral region of Kargi, which receives suppressed rainfall amounts and high temperatures. Droughts and floods have a significant impact on these agro-pastoralists' livelihoods. These protracted and frequent droughts can result in increased vulnerability, crop failure, malnutrition, reduced harvests, and the loss of livelihood. The larger magnitude of floods may be of great advantage if rainwater harvesting is taken into consideration. In conclusion, the region has been exposed to both frequent drought and floods and with prolonged drought, which may adversely affect its livelihoods that are dependent on rains. The communities can take advantage of the severe floods through rainwater harvesting to minimize drought severity and hence gain resilience to floods and droughts. Extreme rainfall, in turn, can enhance the risk of flooding (Blenkinsop et al., 2021) while temperature extremes indicate years of excessive evaporation from water bodies and soils. According to the IPCC's Fifth Assessment Report (IPCC, 2014), the global average temperature increased by 0.85° C (0.65-1.06° C) between 1880 and 2012.

Table 6: Drought severity index for Dakabarichs 1981 – 2021

| *Period of occurrence* | *Peak* | *Duration* | *Severity* | *Intensity* | *Interarrival* |
|---|---|---|---|---|---|
| Jan-1980 to Mar 1982 | Feb 1981 | 27 | 66.87 | 2.674800 | 32 |
| Nov 1982 | Nov 1982 | 1 | 1.05 | 1.050000 | 4 |
| Mar 1983 to Oct 1984 | May 1984 | 20 | 50.65 | 2.532500 | 33 |
| Dec 1985 to Apr 1987 | Mar 1986 | 17 | 26.45 | 1.555882 | 22 |
| Oct 1987 to Mar 1988 | Mar 1988 | 6 | 9.75 | 1.625000 | 36 |
| Oct 1990 to Nov 1990 | Nov 1990 | 2 | 2.45 | 1.225000 | 7 |

| *Period of occurrence* | *Peak* | *Duration* | *Severity* | *Intensity* | *Interarrival* |
|---|---|---|---|---|---|
| May 1991 to Sep 1995 | Jun 1992, May 1994 | 53 | 109.55 | 2.066981 | 55 |
| Dec 1995 to Mar1997 | Mar 1997 | 16 | 34.79 | 2.174375 | 34 |
| Oct 1998 to Oct 2004 | May 2000, | 73 | 190.26 | 2.606301 | 74 |
| Dec 2004 to Feb 2005 | Jan 2005 | 3 | 3.17 | 1.056667 | 4 |
| April 2005 to Sep 2005 | Jun 2005 | 6 | 6.61 | 1.101667 | 7 |
| Nov 2005 to Aug 2007 | Jun 2006 | 22 | 33.94 | 1.542727 | 23 |
| Oct 2007 to Dec 2007 | Dec 2007 | 3 | 3.81 | 1.270000 | 44 |
| Jun 2011 to Jul 2011 | Jun 2011 | 2 | 2.09 | 1.045000 | 6 |
| Dec 2011 | Dec 2011 | 1 | 1.04 | 1.040000 | 28 |
| Apr 2014 to Apr 2015 | Jun 2014 | 13 | 17.63 | 1.356154 | 22 |
| Feb 2016 to Oct 2016 | Mar 2016 | 9 | 12.40 | 1.377778 | 59 |
| Jan 2021 to Nov 2021 | Nov 2021 | 11 | 16.16 | 1.469091 | 12 |

### 3.5 Drought Severity for the Sololo Region

Table 7 depict the analysis of the drought severity index for the Sololo region. In contrast with Dakabaricha Comparable findings were obtained for the predominance of mild drought episodes over moderate drought episodes in the area. There were eleven (11) mild, six (6) moderate, and one (1) severe drought recorded, with the year 2000 seeing the most severe drought. 1982, 1986, 1987, 1988, 1990, 2006, 2009, 2010, 2011, 2014, and 2016 saw mild droughts in Sololo; 1981, 1984, 1992, 1994, 1997, and 2021 saw moderate droughts; and 2000 saw severe droughts (Table 7). Understanding drought severity and frequency is critical for developing initiatives that improve the resilience of pastoral livelihoods and food security in the Sololo region, hence reducing the socioeconomic costs of droughts. The data can help shape regional and national policy, encouraging efforts to reduce drought risks and improve water resource management in drought-prone areas.

Figure 7: Drought severity index for Sololo 1981 – 2021

| *Period of occurrence* | *Peak* | *Duration* | *Severity* | *Intensity* | *Interarrival* |
|---|---|---|---|---|---|
| Jan 1980 to Feb 1981 | Feb 1981 | 12 | 24.86 | 2.071667 | 22 |
| Jan 1982 to Mar 1982 | Mar 1982 | 3 | 3.60 | 1.200000 | 23 |
| Dec 1983 to Jan 1985 | Oct 1984 | 14 | 36.97 | 2.640714 | 25 |
| Jan 1986 to Mar 1986 | Mar 1986 | 3 | 3.51 | 1.170000 | 15 |
| Apr 1987 | Apr 1987 | 1 | 1.30 | 1.300000 | 8 |
| Dec 1987 to Mar 1988 | Mar 1988 | 4 | 5.24 | 1.310000 | 34 |
| Oct 1990 to Dec 1990 | Nov 1990 | 3 | 3.43 | 1.143333 | 6 |

| *Period of occurrence* | *Peak* | *Duration* | *Severity* | *Intensity* | *Interarrival* |
|---|---|---|---|---|---|
| Apr 1991 to Jul 1993 | Aug 1992 | 28 | 61.75 | 2.205357 | 30 |
| Oct 1993 to Aug 1997 | Sep 1994, Mar 1997 | 47 | 110.64 | 2.354043 | 61 |
| Nov 1998 to Jun 2005 | Jul 2000 | 80 | 248.63 | 3.107875 | 84 |
| Nov 2005 to Sep 2008 | Aug 2006 | 35 | 58.31 | 1.666000 | 45 |
| Aug 2009 to Sep 2009 | Sep 2009 | 2 | 2.07 | 1.035000 | 4 |
| Dec 2009 to Feb 2010 | Jan 2010 | 3 | 3.17 | 1.056667 | 4 |
| Apr 2010 to Feb 2011 | Jan 2011 | 11 | 12.08 | 1.098182 | 12 |
| Apr 2011 to Oct 2011 | Sep 2011 | 6 | 6.66 | 1.110000 | 36 |
| Apr 2014 to Oct 2015 | Aug 2014 | 19 | 31.76 | 1.671579 | 20 |
| Dec 2015 to Oct 2016 | Oct 2016 | 11 | 14.43 | 1.311818 | 61 |
| Jan 2021 to Dec 2021 | Jan 2021 | 12 | 33.73 | 2.810833 | 61 |

The most severe flood episode in 2000 had a big positive index of roughly +370, whilst the most severe drought in 1997 had a large negative index of around -530 (Table 8). Based on the data, Sololo's drought and flood patterns appear to be distinct. Droughts and floods have a significant impact on these agro-pastoralists' livelihoods. Prolonged droughts in these agro-pastoral areas can result in economic instability, crop failure, reduced harvests, and animal loss, whereas floods can completely destroy farms, small stocks and destroy the grazing land. In addition, the loss of livestock and crops affects the social fabric of the agro-pastoral communities, impacting their cultural practices and social status leading to societal moral disruption. These challenges underscore the critical need for long-term solutions and support to assist agro-pastoralist communities in adapting to climate change and mitigating the effects of droughts and floods in the study area. In conclusion, the region has been exposed to both frequent drought and floods and with prolonged drought, which may adversely affect its livelihoods that are dependent on rains. The communities can take advantage of the severe floods through rainwater harvesting to minimize drought severity and hence gain resilience to floods and droughts. Climate variability has an impact on pastoral livelihoods by reducing access to rangelands, making it more difficult to move and conduct traditional management methods, reducing herd size and health, and increasing market access. Pastoralism is a naturally resilient livelihood system in the face of growing climate variability, yet pastoralists are nonetheless regarded as the most vulnerable to its consequences. Addressing the underlying social and economic concerns is necessary.

Table 8: Drought severity index for the agro-pastoral region of Dakabaricha and Sololo

| *Wards* | *Years of drought episodes* | *Magnitude* | *Years of flood episodes* | *Magnitude* |
|---|---|---|---|---|
| Dakabaricha | 1983<br>1984<br>1986<br>1987<br>1991 | -220<br>-20<br>-60<br>-70<br>-240 | 1981<br>1982<br>1985<br>1988<br>1990 | +280<br>+250<br>+50<br>+200<br>+180 |

| *Wards* | *Years of drought episodes* | *Magnitude* | *Years of flood episodes* | *Magnitude* |
|---|---|---|---|---|
| | 1992 | -100 | 1997 | +580 |
| | 1993 | -100 | 1998 | +20 |
| | 1995 | -60 | 2002 | +30 |
| | 1996 | -60 | 2004 | +30 |
| | 1999 | -200 | 2006 | +180 |
| | 2000 | -410 | 2011 | +130 |
| | 2001 | -30 | 2013 | +140 |
| | 2003 | -30 | 2018 | +200 |
| | 2005 | -60 | 2019 | +170 |
| | 2007 | -130 | 2020 | +300 |
| | 2008 | -130 | 2021 | +60 |
| | 2009 | -280 | | |
| | 2010 | -210 | | |
| | 2014 | -90 | | |
| | 2016 | -130 | | |
| | 2017 | -90 | | |
| Sololo | 1981 | -320 | 1983 | +260 |
| | 1982 | -180 | 1984 | +200 |
| | 1985 | -40 | 1986 | +120 |
| | 1988 | -70 | 1987 | +80 |
| | 1989 | -80 | 1991 | +200 |
| | 1990 | -90 | 1992 | +180 |
| | 1994 | -80 | 1996 | +230 |
| | 1997 | -560 | 1999 | +360 |
| | 1998 | -100 | 2000 | +370 |
| | 2002 | -200 | 2001 | +180 |
| | 2003 | -200 | 2005 | +200 |
| | 2004 | -60 | 2007 | +170 |
| | 2006 | -300 | 2008 | +120 |
| | 2011 | -140 | 2009 | +200 |
| | 2013 | -280 | 2010 | +80 |
| | 2018 | -300 | 2014 | +120 |
| | 2019 | -100 | 2015 | +20 |
| | 2020 | -130 | 2016 | +80 |
| | 2021 | -150 | 2017 | +70 |

### 3.6 Multinomial Logic Results in the Choice of Livelihoods in the Study Regions

The results of the Multinomial logistic regression of the factors influencing respondents' livelihood choices to climate variability among the pastoral and agro-pastoral communities in the study region are presented in table 9. The Chi-square result was highly significant ($p<0.0000$), indicating that the model had a high level of explanatory power. The pseudo-R2 was 35.48 percent, which showed that the fitted covariates could be linked to how households made their way of life. The model performed well in terms of consistency with a priori expectations on the relationship between the dependent and explanatory variables. It should be noted that the study did not include casual labour, shop-keeping, or both skilled and unskilled wage labour. This has been captured under the heading 'other options' category of livelihood. The model results show that the coefficient of marital status was negatively and significantly ($p<0.05$) related to the likelihood of the household choosing other livelihood options as their primary source of income compared to livestock keeping. This means that married respondents are less likely to choose alternative sources of income besides livestock keeping. Analyzing how marital status affects a household's livelihood choices, Oluwatayo & Ojo (2016) found that marital status positively

correlates with the likelihood of adopting an adaptation strategy, a finding closely relating to the present study, where married household had preferred choice over the production systems and activities to engage in. Because most respondents in this study were married, it was envisaged that they could engage in other economic activities to support their families. A study by Aelst & Holvoet (2016) found that the intersection of marital status had an impact on a farmer's positioning in terms of choice of livelihood. We think that contrary to our finding of farmers not choosing other livelihoods than livestock when married, this could be a factor of cultural preference for livestock keeping. Still, the expected marriage to provide family members with the opportunity to have divergent views and consultative aspects on choosing other livelihood choices is not so clear to us. The results demonstrate that household size is negatively and significantly ($p<0.05$) connected to the likelihood of the household choosing other livelihood options as their primary source of income instead of livestock keeping. As a result, families with many members are more likely to keep livestock, which is their principal source of livelihood. This could be related to higher household sizes, which provide the necessary labour for livestock rearing.

Education was associated with a higher likelihood of a household choosing salaried employment and crop farming over livestock keeping ($p< 0.05$). This suggests that educated household heads are more likely to choose formal employment and crop farming over livestock keeping. In response to climate variability, decisions about livelihood options among pastoral and agro-pastoral households are critical strategies for reducing poverty and food insecurity in the study region. People choose their livelihood based on the level of their household assets or the availability of infrastructure in their community (Gebru and Beyene, 2012). The household's head education level influenced adaptation through improved livestock productivity and better agro-ecological farming practices. Education enables formal employment and thus capital, as well as getting to appreciate knowledge in farming fast, resulting in a shift in livelihood options from the ability to know about technologies and existing strategies that work for adoption. Similarly, climate variability has resulted in the depletion of natural forage resources on which animals rely for survival, making livestock farming in pastoral and agro-pastoral regions labour-intensive.

Household adoption of a new crop variety (drought tolerant) was positively and significantly ($p<0.05$) related to the likelihood of a household choosing crop farming as its primary source of income over livestock keeping. This could be a result of inadequate rainfall/water, which makes the households adopt drought-tolerant and early maturing crops to sustain themselves during the heights. Changes in crop types in arid and semi-arid regions during prolonged dry periods may result in increased yields as long as water harvesting technologies and the right crop season timing are used, prompting households to choose crop production over livestock keeping.

Changes in planting methods (closed ridges) were also related to the possibility of a household preferring business over livestock keeping ($p< 0.05$). Planting crops on closed banks conserves water, reducing the likelihood of crop failure during inadequate rainfall. This means that, compared to households that do not change their crop planting methods, families that adopt new crop planting methods engage in business rather than livestock keeping. Mixed cropping and rotational cropping within the seasons are two of the observed strategies adopted by the respondents. This is a result of variations in the seasonal rainfall that lead to the failure of some crops.

Compared to livestock keeping, the integrated pest management coefficient was positively and significantly ($p<0.05$) related to the likelihood of a household choosing crop farming as their primary source of income. Furthermore, crop pest management improves crop yield, making crop farming an option for livelihood diversification in addition to livestock keeping, which is the main livelihood. Adoption of adapted livestock species such as camels was negatively and significantly ($p<0.05$) related to a household's preference for crop farming over livestock keeping. This is due to the fact

that adapted livestock practices attract higher paybacks from livestock keeping, making it a preferred livelihood option over crop farming.

The likelihood of a household choosing business and crop farming over livestock keeping was negatively and significantly ($p<0.05$) related to forest product collection. This is due to the fact that the advantages of forest products (firewood, wild fruits) may outweigh the benefits of running a business and crop farming. It could also be because collecting forest products does not require an initial investment and saves time. As a result, household members will have more time to devote to livestock keeping, which is less time-consuming. The possibility of collecting forest products while keeping livestock is more significant than operating a business or crop farming. The likelihood of a household choosing business and crop farming over livestock keeping was positively and significantly ($p<0.05$) related to biodiversity conservation, as represented by the positive MLM values of 1.534 and 1.111, respectively. This could be because business and crop farming do not lead to land degradation compared to livestock keeping, which can disrupt ecosystem conservation through overgrazing. Pastoral and agro-pastoral communities keep a large number of livestock to cushion themselves against the impacts of climate variability. This large number of animals destroys the environment, which is already affected by climate change. However, it is negatively related to the use of various crop varieties and irrigation, though not statistically significant.

Starting or expanding petty trade and intensifying water harvesting and storage measures were negatively and significantly ($p<0.05$) related to the likelihood that the household chooses other livelihood options over livestock keeping. This could be because the two require capital, which can be obtained through the sale of livestock and livestock products, as opposed to other livelihood options. Organizing pastoralists in groups will create jobs for many people and positively impact the development of local economies. The study looked at the influence of household size on livelihood choices, and in corroboration with empirical literature, larger family sizes enabled farmers to implement labour-intensive adaptation measures (Nhemachena and Hassan, 2008; Aymone, 2009). As a result, it is envisaged that larger households are likely to shift to farming, significantly influencing the smallholder's adaptation to climate variability in the study area. This implies that families with a high proportion of farming members are more likely to be better adapted to climate variability. The observed choice of farming in the study areas could be a result of the increasing human population, leading to the shrinking of previous extensive farmlands, and thus, as a coping strategy, more pastoralists are becoming agro-pastoralists. This could also be exacerbated by the earlier discussed access to education and knowledge, as well as the availability of technologies for farming. A larger household workforce facilitates adaptation (Bryan et al., 2009) and increases agricultural production since it enhances labour-intensive farming practices, a finding that was also reported by other studies (Khan et al., 2022; Belay et al., 2022; Aryal et al., 2022). The number of household members involved in farming significantly influenced the household's adaptation level to climate variability. This implies that families with a high proportion of farming members are more likely to have a high level of adaptation to climate variability. This was explained in terms of labour availability, where households with more members involved in farming activities have higher labour endowment capacity (Mugi-Ngenga et al., 2016; Deininger et al., 2022). Those households have more labour at the needed peak seasons when external labour is expensive and difficult to obtain, which is thus advantageous to their household labour. Therefore, households with a larger pool of labour are more likely to adopt agricultural technology and use it more intensively (Mignouna et al., 2011; Chen et al., 2022). Higher numbers of households are more likely to adapt to perceived climate variability and having a larger household workforce facilitates adaptation (Bryan et al., 2009) and increases agricultural production because it is linked with labour-intensive farming practices. As a result, household size is associated with the observed adaptation measures, a finding that corroborates the work of Belay et al. (2017), where household size was noted to be an

essential factor in farming and the adoption of technologies. To account for the role of household labour in the adoption decision, members of larger households were more likely to adopt than members of smaller households (Gomez, 2014). Nonetheless, the increasing number of households increases the likelihood of adaptation, but at the cost of increased need for sustenance, which may result in over-exploitation of resources, a threat to the sustainability of farming. However, other studies contradicted our findings that it is possible to conclude that the greater the number of households, the fewer the adaptation strategies to climate variability (Vijayasarathy and Ashok, 2015), which could be because of resource competition, and thus, depending on locations and resources available, mainly land, adaptation and diversification of livelihoods in farming could be curtailed. The empirical findings suggest that increasing smallholder farmers' access to off-farm sources of income increases their likelihood of investing in farming activities (Aymone, 2009). The assumption was that households with credit services had more financial capital to take advantage of technological progress and withstand the effects of climate variability and were thus less likely to perceive climate variability (Habtemariam et al., 2016). Households with access to credit are more likely to use climate-risk coping strategies (Rahut and Ali, 2017). It is also an essential component of expanded institutional support for encouraging adaptation options to mitigate the adverse effects of climate change (Temesgen et al., 2009). The study found that agro-pastoral communities were more willing to adopt climate-smart farming technologies. However, access to initial capital to access the infrastructure and inputs still limited the rates of adoption. Other studies corroborate our findings, where diversity in climate change adaptation strategies was reported to highly depend on access to credit or off-farm incomes (Awiti et al., 2023; Chepkoech et al., 2023; Hammond et al., 2023)

Table 9: Multinomial logistic regression results on choices of livelihood by households

| *Variable* | *Business (2)* | *Crop farming (3)* | *Mixed farming (4)* | *Other livelihood options (5)* | *Relief (6)* | *Remittances (7)* | *Salaried employment (8)* |
|---|---|---|---|---|---|---|---|
| Gender of household head (Male) | 0.082 | 0.369 | 0.309 | 2.473 | 14.243 | 2.454 | -0.367 |
| | (0.763) | (0.490) | (1.805) | (1.679) | (1866.776) | (1.850) | (1.299) |
| Marital status (Married) | -0.366 | -0.421 | -2.382 | 1.177 | 0.278 | -19.250 | 18.190 |
| | (0.884) | (0.584) | (1.825) | (1.946) | (6992.978) | (2691.384) | (9087.537) |
| Household size (7 & above) | -1.196 | -0.115 | 0.631 | -3.424 | -2.156 | -25.421 | 0.449 |
| | (0.708) | (0.397) | (1.169) | (1.852) | (3335.118) | (3110.440) | (1.059) |
| Education (Educated) | 0.463 | 0.845* | 0.441 | -2.335 | 14.551 | -21.996 | 2.585* |
| | (0.658) | (0.418) | (1.321) | (1.807) | (1752.119) | (4685.845) | (1.273) |
| Change in crop variety (resistant variety) | 0.770 | 1.687* | 0.446 | 0.705 | 15.375 | -12.053 | -2.129 |
| | (0.959) | (0.531) | (1.256) | (1.217) | (7400.636) | (2125.166) | (1.515) |
| Change in planting method (closed ridges) | 2.398* | -1.101 | -0.880 | -15.992 | 3.151 | 9.947 | -0.410 |
| | (1.063) | (0.766) | (1.762) | (3725.759) | (7332.701) | (4027.843) | (1.644) |
| Crop rotation | -2.182 | 0.574 | -1.848 | -19.872 | -8.758 | -27.494 | 1.551 |
| | (1.223) | (0.574) | (1.989) | (3622.501) | (6842.136) | (4070.040) | (1.390) |
| Integrated pest management | 1.488 | 2.570** | 3.008 | -13.526 | 10.413 | 3.254 | 0.178 |
| | (1.170) | (0.698) | (1.810) | (3926.325) | (8188.122) | (4129.438) | (1.530) |
| Involvement of adopted livestock species | -1.024 | -1.046* | -1.849 | -21.141 | 13.069 | -0.484 | 0.020 |
| | (0.652) | (0.434) | (1.272) | (4112.576) | (1868.637) | (1.518) | (1.094) |

| *Variable* | *Business (2)* | *Crop farming (3)* | *Mixed farming (4)* | *Other livelihood options (5)* | *Relief (6)* | *Remittances (7)* | *Salaried employment (8)* |
|---|---|---|---|---|---|---|---|
| Forest product collection | -1.913* | -2.515** | -20.269 | -0.159 | -17.194 | 14.387 | -0.852 |
| | (0.801) | (0.506) | (9563.599) | (1.425) | (1848.670) | (3390.874) | (1.347) |
| Conservation of biodiversity | 1.534* | 1.111* | 2.068 | 0.701 | -13.686 | 14.141 | 0.135 |
| | (0.721) | (0.432) | (1.333) | (1.415) | (1854.802) | (1752.622) | (1.286) |
| Start Small Scale Irrigation | 1.618 | 18.634 | 16.179 | 1.919 | 15.740 | 15.543 | 0.929 |
| | (1.200) | (1468.891) | (3742.163) | (1.588) | (9610.502) | (5770.398) | (1.831) |
| Practice agro-Forestry | 0.279 | 1.410 | 1.207 | 1.924 | 0.355 | 1.174 | -0.343 |
| | (1.331) | (1.330) | (4547.866) | (1.677) | (14955.06) | (8855.695) | (1.978) |
| Engage in Non-Farm Income Activities | -2.112 | -0.914 | 13.551 | 16.745 | -2.303 | 14.204 | -3.178 |
| | (1.127) | (1.017) | (4587.729) | (3759.278) | (19525.61) | (4758.334) | (2.200) |
| Start or Expand Petty Trade | 0.497 | -0.490 | 13.252 | -3.054* | 13.367 | 0.153 | 2.270 |
| | (1.385) | (0.947) | (3459.557) | (1.425) | (8192.395) | (8032.708) | (2.615) |
| Join Local farmer Groups | 18.282 | -0.154 | 14.252 | 19.765 | -0.678 | 0.731 | 0.966 |
| | (4321.386) | (0.856) | (4337.772) | (3491.888) | (25972.15) | (6248.821) | (2.166) |
| Intensify Water Harvesting and Storage Measures | -1.214 | -1.518 | 13.829 | -4.961* | 14.666 | -2.088 | -2.618 |
| | (1.455) | (1.229) | (5997.617) | (1.505) | (29106.85) | (8218.782) | (1.371) |
| *Statistics: chi2 (77) = 220.45; prob > chi = 0.0000; Pseudo - R2 = 0.3548; Number of observations= 275; Note: (1) Livestock keeping is the comparison category. The figures in parenthesis are standard errors. **p < 0.01; *p<0.05.* | | | | | | | |

## 4. Conclusion and Recommendation

Sololo's drought and flood patterns seemed to be unique as compared to the other wards. The drought episodes seem to be larger in magnitude as compared to flood episodes, though with the same frequency of occurrence, and again, the worst floods were experienced in the year 2000 when the other three wards were experiencing the worst droughts. Maikona, Kargi, and Dakabaricha experienced more drought episodes as compared to floods, but of a lesser magnitude. Prolonged droughts were experienced for as long as 4 years in Sololo, 6 years in Maikona and Kargi, and 5 years in Dakabaricha. These Prolonged droughts can cause crop failure, depressed harvests, and loss of animals, while the flood episodes can sweep away farms and animals. The larger magnitude of floods may be of great advantage if rainwater harvesting is taken into consideration.

In conclusion, the region has been exposed to both frequent drought and floods and with prolonged drought, which may adversely affect its livelihoods that are dependent on rains. The communities can take advantage of the severe floods through rainwater harvesting to minimize drought severity and hence gain resilience to floods and droughts.

Both the pastoral (Kargi, Maikona) and agro-pastoral (Dakabaraicha, Sololo) regions of the study have all been experiencing climate extremes in the form of drought, floods, warmer temperatures, and cooler temperatures. Dakabaricha exhibited higher magnitudes and frequencies of drought and warmer temperatures as compared to floods and cooler temperatures while Kargi, Maikona, and Sololo have been experiencing higher frequencies of warmer temperatures and flood episodes while the magnitudes of cooler temperatures and drought episodes have been relatively lower.

It is imperative that Dakabaricha could be more vulnerable to agricultural and meteorological drought than it was earlier. The county is experiencing both drought and flood episodes coupled with the existence of warmer and cooler episodes is an indication of climate variability that may affect agricultural and livestock production hence rendering the county vulnerable to famine, human-to-human conflict, human-wildlife conflicts, and loss of livelihoods, property and arable land. This study shows that Marsabit County is affected by climate variability hence its ecosystems are fragile and may be affecting the livelihoods of the communities who are mainly pastoralists.

This study was aimed at determining the choices that the pastoralists and agro-pastoralist communities of Northern Kenya, Marsabit County, take to adapt to the negative impacts of climate change. The study finds education level to be a significant positive influence on the choice of livelihood, and thus, efforts to increase both children's education and adult education could increase communities' choices on climate-smart livelihood choices and, hence, more community resilience. Notably, the study notes that the social, economic, and biophysical aspects are determinants that influence households' choice of livelihoods and are also factors that determine households' vulnerability to climate-induced stresses.

This study recommends that policies with emphasis on promoting education, supporting extension services, enhancing diversification of income sources and access to credit, supporting herd mobility and diversity, creating employment, and increasing access to markets and early warning information are likely to improve pastoral household's livelihoods. This study generally calls for more focus on climate-smart agricultural practices to enable sustainable farming which is the most preferred amidst climate extremes to maintain arable land of Marsabit County. Similarly, the study calls for a review of suitable livestock breeds in the wake of climate variability to encourage the communities to choose livestock production which was the least preferred due to the associated impacts of drought and floods on the current breeds. The study highly recommends the employment of good agricultural practices and research on drought-tolerant crop varieties and livestock breeds suitable for the region under climate variability to enable the communities to cope with drought, floods, and the shift in weather patterns shown in the study.

This study recommends arrangements for feeding programs during floods and droughts given that the communities purely rely on agro-pastoral activities. This study recommends assistance to the pastoral and agro-pastoral communities with rainwater harvesting structures to take advantage of the flood episodes and minimize loss during drought episodes. This study generally calls for more focus on climate-smart agricultural practices to enable sustainable farming which is the most preferred amidst climate extremes to maintain arable land of Marsabit County. Similarly, the study calls for a review of suitable livestock breeds in the wake of climate variability to encourage the communities to choose livestock production which was the least preferred due to the associated impacts of drought and floods on the current breeds. The study's findings aim to improve understanding of drought and its features, as well as the science of drought prediction in Marsabit County. This will supplement local and national government's efforts to create long-term drought resilience initiatives and contingency response plans.

## 5. Acknowledgment

We want to express our gratitude to the Kenya Climate Smart Agriculture Project (KCSAP) for financially supporting my studies and the local leaders and pastoralists of Kargi, Maikona, Sololo, and Dakabaricha wards for their participation in this study. We also wish to acknowledge the Kenya Meteorological Department, the European Centre for Medium-Range Weather Forecasts, and the IGAD Climate Prediction and

Applications Centre in Nairobi, Kenya, for providing decadal data for study sites.

## 6. References

Aelst, K. V., & Holvoet, N. (2016). Intersections of Gender and Marital Status in Accessing Climate Change Adaptation: Evidence from Rural Tanzania. *World Development*, *79*, 40-50. https://doi.org/10.1016/j.worlddev.2015.11.003.

Ahmad, M. M., Yaseen, M., & Saqib, S. E. (2022). Climate change impacts of drought on the livelihood of dryland smallholders: Implications of adaptation challenges. *International Journal of Disaster Risk Reduction*, *80*, 103210. Retrieved from: https://api.semanticscholar.org/CorpusID:251423689.

Aryal, J. P., Manchanda, N., & Sonobe, T. (2022). Expectations for household food security in the coming decades: A global scenario. In Future Foods (pp. 107-131). Academic Press. https://doi.org/10.1016/B978-0-323-91001-9.00002-5.

Awiti, H. A., Gido, E. O., & Obare, G. A. (2023). Crop mix portfolio response to climate risks: evidence from smallholder farmers in Kisumu County, Kenya. *Agrekon*, *61*(2), 192-206. Retrieved from: https://api.semanticscholar.org/CorpusID:246593713.

Aymone, G. G., 2009. Understanding farmers' perceptions and adaptation to climate change and variability: The case of the Limpopo basin, South Africa. IFPRI Discussion paper 00849, International Food Policy Research Institute, Washington DC.

Ayugi, B., Tan, G., Niu, R., Dong, Z., Ojara, M., Mumo, L., & Ongoma, V. (2020). Evaluation of Meteorological Drought and Flood Scenarios over Kenya, East Africa. *Atmosphere*, *11*(3), 307, https://doi.org/10.3390/atmos11030307.

Balling, R. C., Keikhosravi Kiany, M. S., Sen Roy, S., & Khoshhal, J. (2016). Trends in extreme precipitation indices in Iran: 1951-2007. *Advances in Meteorology*, *2016*, https://doi.org/10.1155/2016%2F2456809.

Belay, A., Oludhe, C., Mirzabaev, A., Recha, J. W., Berhane, Z., Osano, P. M., Demissie, T., Olaka, L. A., & Solomon, D. (2022). Knowledge of climate change and adaptation by smallholder farmers: evidence from southern Ethiopia. *Heliyon*, *8*(12), e12089, https://doi.org/10.1016/j.heliyon.2022.e12089.

Belay, A., Recha, J. W., Woldeamanue, T., & Morton, J. F. (2017). Smallholder farmers' adaptation to climate change and the determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security*, *6*, 24. Retrieved from: https://api.semanticscholar.org/CorpusID:24553819.

Blenkinsop, S., Muniz, L., & Smith, A.J.P. (2021). Climate change increases extreme rainfall and the chance of floods. *Sci. Brief Rev.*, *2021*, 1–5, https://doi.org/10.5281/ZENODO.4779119.

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy*, *12*(4), 413-426, https://doi.org/10.1016/j.envsci.2008.11.002.

CELEP (Coalition of European Lobbies on Eastern African Pastoralism) (2017). Recognizing the role and value of pastoralism and pastoralists. *Policy Brief*, *1*(1). Retrieved from: https://www.celep.info/wp-content/uploads/2014/05/CELEP-value-of-pastoralism-position-paper.pdf.

Chen, T., Rizwan, M., & Abbas, A. (2022). Exploring the role of agricultural services in production efficiency in Chinese agriculture: A case of the socialized agricultural service system. *Land*, *11*(3), 347, https://doi.org/10.3390/land11030347.

Chepkoech, W., Stöber, S., Kurgat, B. K., Bett, H. K., Mungai, N. W., & Lotze-Campen, H. (2023). What drives diversity in climate change adaptation strategies for African indigenous vegetable production in Kenya? *Economic Analysis and Policy*, *77*, 716-728, https://doi.org/10.1016/j.eap.2022.12.016.

Dai, A. (2013). Increasing drought under global warming in observations and models. *Nature Climate Change*, *3*(1), 52–58, https://doi.org/10.1038/nclimate1633.

Deininger, K., Jin, S., & Ma, M. (2022). Structural transformation of the agricultural sector in low-and middle-income economies. *Annual Review of Resource Economics*, *14*, 221-241, http://dx.doi.org/10.1146/annurev-resource-111820-033252.

Ericksen, P., De Leeuw, J., Thornton, P. K., Ayantunde, A., Said, M., Herrero, M., & Notenbaert, A. (2013). Climate change in sub-Saharan Africa: What consequences for pastoralism? In: Catley, A., Lind, J., & Scoones, I (eds.), Pastoralism and Development in Africa, Dynamic Change at the Margins. London: Routledge, pp 71–81.

FAO (Food and Agriculture Organization of the UN) (2021). Boosting smallholder resilience for recovery: Safeguard vulnerable pastoralist and agro-pastoralist households in East and West Africa and the Sahel. Accra, Ghana: FAO COVID-19 Response and Recovery Programme, https://doi.org/10.4060/cb3768en.

Fisher, A. A., Laing, J. E., Stoeckel, J. E., and Townsend, J. W., (1991). Handbook for Family Planning Operations Research Design. Population Council, New York.

Gebrechorkos, S. H., Hülsmann, S., & Bernhofer, C. (2019). Changes in temperature and precipitation extremes in Ethiopia, Kenya, and Tanzania. *Int. J. Climatol.*, *39*(1), 18–30, https://doi.org/10.1002/joc.5777.

Gebru, G. W., & Beyene, F. (2012). Rural household livelihood strategies in drought-prone areas: A case of Gulomekeda District, eastern zone of Tigray National Regional State, Ethiopia. *J. Dev. Agric. Econ.*, *4*(6), 158-168, http://dx.doi.org/10.5897/JDAE12.126.

Gomez, N. (2014). Climate change and adaptation on selected crops in Southern Philippines. *International Journal of Climate Change Strategies and Management,* *7*(3), 290-305. Retrieved from: https://api.semanticscholar.org/CorpusID:152883107.

Green, W. H. (2003). Econometric Analysis (5th ed.). Upper Saddle River, NJ: Pearson Education.

Habtemariam, L. T., Gandorfer, M., Kassa, G. A., & Heissenhuber, A. (2016). Factors Influencing Smallholder Farmers' Climate Change Perceptions: A Study from Farmers in Ethiopia. *Environmental Management*, *58*, 343-358. Retrieved from: https://api.semanticscholar.org/CorpusID:4477016.

Hammond, J., Pagella, T., Caulfield, M. E., Fraval, S., Teufel, N., Wichern, J., Oosting, S. J., de Boer, I. J. M., Lannerstad, M., Waha, K., Rosenstock, T. S., Giller, K. E., Herrero, M., Harris, D., & van Wijk, M. T.(2023). Poverty dynamics and the determining factors among East African smallholder farmers. *Agricultural Systems*, *206*, 103611, https://doi.org/10.1016/j.agsy.2023.103611.

IPCC (Intergovernmental Panel on Climate Change) (2007). Climate change 2007: Synthesis report. Contribution of working Groups, I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change [Pachauri, R.K and Reisinger, A. (Eds.)]. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

IPCC (Intergovernmental Panel on Climate Change) (2019). Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

IPCC (Intergovernmental Panel on Climate Change) (2014). Climate Change (2014). Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 151 pp.

Kalinda, T., & Langyintuo, A. (2014). Livelihood Strategies, Shocks and Coping Mechanisms among Rural Households in Southern Zambia. *Curr. Res. J. Soc. Sci.*, *6*(4), 120-133, http://dx.doi.org/10.19026/crjss.6.5214.

Khan, N. A., Shah, A. A., Chowdhury, A., Tariq, M. A. U. R., & Khanal, U. (2022). Rice farmers' perceptions about temperature and rainfall variations, respective

adaptation measures, and determinants: Implications for sustainable farming systems. *Frontiers in Environmental Science*, *10*, 1972. https://doi.org/10.3389/fenvs.2022.997673.

Le, P. V., Phan-Van, T., Mai, K. V., & Tran, D. Q. (2019). Space–time variability of drought over Vietnam. International Journal of Climatology, *39*(14), 5437-5451, https://doi.org/10.1002/joc.6175.

Mignouna, B., Manyong, M., Rusike, J., Mutabai, S., & Senkondo, M. (2011). Determinants of adopting Imazapyr-resistant maize technology and its impacts on household income in Western Kenya: AgBioforum. In: Hall, B. (Ed.), 2002. Adoption of New Technology, New Economy Handbook, 14, pp. 158-163. Retrieved from: https://api.semanticscholar.org/CorpusID:129962534.

Mohamed, A. A. (2019). Pastoralism and development policy in Ethiopia: A review study. *BIRCI Journal: Humanities*, *2*(4).

Mugi-Ngenga, E. W., Mucheru-Muna, M. W., Mugwe, J. N., Ngetich, F. K., Mairura, F. S., & Mugendi, D. N. (2016). Household's socio-economic factors influencing the level of adaptation to climate variability in the dry zones of Eastern Kenya. *Journal of Rural Studies*, *43*, 49-60, https://doi.org/10.1016/j.jrurstud.2015.11.004.

Muller, J. C., & Cross, R. (2014) Adapting to climate change and addressing drought – learning from the Red Cross Red Crescent experiences in the Horn of Africa. *Weather and Climate Extremes*, 1–6, https://doi.org/10.1016/j.wace.2014.03.009.

Mutura, J. K., Nyairo, N., Mwangi, M., & Wambugu, S. K. (2013). Vertical and Horizontal Integration as Determinants of Market Channel Choice among Smallholder Dairy Farmers in Lower Central Kenya. *Asian Journal of Economics and Empirical Research*, *2*(2), 83-90.

Mwangi, E. W. F. (2014). Forecasting Droughts in East Africa. *Hydrology and Earth System Sciences*, *18*(2), 611-620, https://doi.org/10.5194/hess-18-611-2014.

Nhemachena, C. and Hassan, R. (2008). Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute. Washington DC. Retrieved from: https://api.semanticscholar.org/CorpusID:128561678.

Nkamleu, G. B., & Kielland, A. (2006). Modeling farmers' decisions on child labor and schooling in the cocoa sector: A multinomial logit analysis in Côte d'Ivoire. *Agricultural Economics*, *35*(3), 319-333.

Ogundeji, A. A., Danso-Abbeam, G., & Jooste, A. (2022). Climate information pathways and farmers' adaptive capacity: Insights from South Africa. *Environmental Development*, *44*, 100743, https://doi.org/10.1016/j.envdev.2022.100743.

Oluwatayo, I. B., & Ojo, A. O. (2016). Awareness and Adaptation to Climate Change among Yam-Based Farmers in Rural Oyo State, Nigeria. *The Journal of Developing Areas,* *50*(2). Retrieved from: https://api.semanticscholar.org/CorpusID:156160951.

Ongoma, V., Chen, H., & Omony, G. W. (2018). Variability of extreme weather events over the equatorial East Africa, a case study of rainfall in Kenya and Uganda. *Theoretical and Applied Climatology*, *131*(1-2), 295-308, https://doi.org/10.1007/s00704-016-1973-9.

Opiyo, F. E. O., Wasonga, O. V., & Nyangito, M. M. (2014). Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya: Implications for resilience programming. *Pastoralism*, *4*(1), 1–15, https://doi.org/10.1186/s13570-014-0010-9.

Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., & Munang, R. (2015). Drought Adaptation and Coping Strategies among the Turkana Pastoralists of Northern Kenya. *International Journal of Disaster Risk Science*, *6*(3), 295–309, https://doi.org/10.1007/s13753-015-0063-4.

Palmer, W. C. (1965). Meteorological drought. In: U.S. Weather Bureau Res. Pap. No. 45 (p. 58). Retrieved from: https://www.ncdc.noaa.gov/temp-and-precip/drought/docs/palmer.pdf.

PCGCC (Pew Center on Global Climate Change) (2004). Coping with global climate change: The role of adaptation in the United States. PCGCC: Arlington. Retrived from: https://api.semanticscholar.org/CorpusID:126739113.

Polong F, Chen H, Sun S, Ongoma V (2019) Temporal and spatial evolution of the standard precipitation evapotranspiration index (SPEI) in the Tana River basin, Kenya. *Theoretical and Applied Climatology*, *138*(1–2), 777–792, https://doi.org/10.1007/s00704-019-02858-0.

Rahimi, J., Fillol, E., Mutua, J. Y., Cinardi, G., Robinson, T. P., Notenbaert, A. M., & Butterbach-Bahl, K. (2022). A shift from cattle to camel and goat farming can sustain milk production with lower inputs and emissions in north sub-Saharan Africa's drylands. *Nature Food*, *3*(7), 523-531. Retrieved from: https://api.semanticscholar.org/CorpusID:250976780.

Rahut, D. B., & Ali, A. (2017). Coping with climate change and its impact on productivity, income, and poverty: Evidence from the Himalayan region of Pakistan. *International Journal of Disaster Risk Reduction*, 2212-4209, https://doi.org/10.1016/j.ijdrr.2017.05.006.

Sheffield, J., Woo, E. F., & Roderick, M. L. (2012). Little change in global drought over the past 60 years. *Nature*, *491*(7424), 435–438, https://doi.org/10.1038/nature11575.

Silvestri, S., Bryan, E., Ringler, C., Herrero, M., & Okoba, B. (2012). Climate change perception and adaptation of agro-pastoral communities in Kenya. *Regional Environmental Change*, *12*(4), 791–802.

Spinoni, J., Barbosa, P., Bucchignani, E., Cassano, J., Cavazos, T., Christensen, J. H., & Vogt, J. V. (2020). Future Global Meteorological Drought Hot Spots: A Study Based on CORDEX Data. *Journal of Climate*, *33*(9), 3635-3661, https://doi.org/10.1175/JCLI-D-19-0084.1.

Temesgen, D., Hassan, R.M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, *19*, 248-255. https://doi.org/10.1016/j.gloenvcha.2009.01.002.

Thornthwaite, C. W. (1948). An Approach toward a Rational Classification of Climate. *Geographical Review*, *38*(1), 55-94, https://doi.org/10.2307/210739.

Tofu, D. A., Fana, C., Dilbato, T., Dirbaba, N. B., & Tesso, G. (2023). Pastoralists' and agro-pastoralists' livelihood resilience to climate change-induced risks in the Borana zone, south Ethiopia: Using resilience index measurement approach. *Pastoralism*, *13*(1), 4, http://dx.doi.org/10.1186/s13570-022-00263-3.

Vijayasarathy, K., & Ashok, K. R. (2015). Climate Adaptation in Agriculture through Technological Option: Determinants and Impact on Efficiency of Production. *Agricultural Economics Research Review*, *28*(1), 103-116, http://dx.doi.org/10.5958/0974-0279.2015.00008.7.

Wells, N., Goddard, S., & Hayes, M. J. (2004). A self-calibrating Palmer Drought Severity Index. *Journal of Climate*, *17*(12), 2335–2351, https://doi.org/10.1175/1520-0442(2004)017.

WMO (World Meteorological Organization) (2019). State of the Climate in Africa. World Meteorological Organization (WMO), Geneva 2, Switzerland.

WMO (World Meteorological Organization) (2017). Guidelines on the Calculation of Climate Normals. WMO-No. 1203, 1203, 29. Retrieved from: https://library.wmo.int/doc_num.php?explnum_id=4166.

Yevjevich, V. M. (1969). An Objective Approach to Definitions and Investigations of Continental Hydrologic Droughts. Hydrology Paper No. 23, Colorado State University, Fort Collins, Colorado.

Zargar, A., Sadiq, R., Naser, B., & Khan, F. I. (2011). A review of drought indices. *Environmental Reviews*, *19*(NA), 333–349, https://doi.org/10.1139/a11-013.

Zhao, T., & Dai, A. (2017). Uncertainties in historical changes and future projections of drought. Part I: Estimates of historical drought changes. *Climatic Change*, *144*(3-4), 519–533, https://doi.org/10.1007/s10584-016-1705-2.

## Author's Declarations and Essential Ethical Compliances

*Authors' Contributions (in accordance with ICMJE criteria for authorship)*

| Contribution | Author 1 | Author 2 | Author 3 |
|---|---|---|---|
| Conceived and designed the research or analysis | Yes | Yes | Yes |
| Collected the data | Yes | No | No |
| Contributed to data analysis & interpretation | Yes | No | No |
| Wrote the article/paper | Yes | No | No |
| Critical revision of the article/paper | Yes | Yes | Yes |
| Editing of the article/paper | Yes | Yes | Yes |
| Supervision | No | Yes | Yes |
| Project Administration | Yes | No | No |
| Funding Acquisition | Yes | No | No |
| Overall Contribution Proportion (%) | 50 | 25 | 25 |

*Funding*
We want to express our gratitude to the Kenya Climate Smart Agriculture Project (KCSAP) for financially supporting my studies and the local leaders and pastoralists of Kargi, Maikona, Sololo, and Dakabaricha wards for their participation in this study. We also wish to acknowledge the Kenya Meteorological Department, the European Centre for Medium-Range Weather Forecasts, and the IGAD Climate Prediction and Applications Centre in Nairobi, Kenya, for providing decadal data for study sites.

*Research involving human bodies or organs or tissues (Helsinki Declaration)*
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

*Research involving animals (ARRIVE Checklist)*
The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

*Research on Indigenous Peoples and/or Traditional Knowledge*
The author(s) solemnly declare(s) that this research has not involved Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

*Research involving Plants*
The author(s) solemnly declare(s) that this research has not involved the plants for experiment and field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

*Research Involving Local Community Participants (Non-Indigenous) or Children*
The author(s) solemnly declare(s) that this research has not directly involved any local community participants or respondents belonging to non-Indigenous peoples. Neither

this study involved any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

*PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)*
The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

*Competing Interests/Conflict of Interest*
Author(s) has/have no competing financial, professional, or personal interests from other parties or in publishing this manuscript. There is no conflict of interest with the publisher or the editorial team or the reviewers.

*Attribution and Representation*
All opinions and mistakes are the author(s)' own and cannot be attributed to the institutions they represent. The publisher is also not responsible either for such opinions and mistakes in the text or graphs or images.

*Declaration of the Use of AI*
During the preparation of this work, the authors used no AI.

## Rights and Permissions

**Open Access.** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

***

To see original copy of these declarations signed by Corresponding/First Author (on behalf of other co-authors too), please download associated zip folder [Ethical Declarations] from the published Abstract page accessible through and linked with the DOI: https://doi.org/10.33002/pp0302.